

## METHOD FOR PRODUCING HOLLOW BLADES

[0001] The present invention relates to a method for manufacturing hollow blades, in particular for gas turbines, according to the definition of the species set forth in claim 1.

[0002] Present-day gas turbines, in particular aircraft engines, must meet exceedingly stringent requirements in terms of reliability, weight, performance, economy and service life. In recent decades, aircraft engines have been developed, particularly for use in the civil sector, which have fully satisfied the above requirements and have attained a high level of technical perfection. The selection of material, the search for new types of suitable material, as well as the quest for novel manufacturing processes play a decisive role in aircraft engine development.

[0003] To reduce the weight of gas turbine components, it is already known from the related art to design gas turbine blades as hollow blades. The blades of a gas turbine account namely for a considerable proportion of its weight. The more appreciably the weight of the gas turbine can be reduced, the more favorable the so-called thrust-to-weight ratio of the aircraft engine is obtained, which is a decisive feature for aircraft engines in terms of achieving a competitive advantage.

[0004] A related art method commonly used for manufacturing hollow blades is the so-called SPF DB method, SPF being an acronym for super plastic forming and DB an acronym for diffusion bonding. In the SPF DB method for manufacturing hollow blades, at least three elements are arranged one over another in a sandwich-type structure, joined to one another at least in portions thereof by diffusion welding, and subsequently superplastically deformed by inflation or blow-up processes. A first element forms a first outer wall of the hollow blade to be manufactured, a second element forms a second outer wall of the hollow blade to be manufactured, and a third element, which is placed prior to the diffusion welding process in a sandwich-type structure between the first and the second element, forms a middle element of the hollow blade to be manufactured that extends in between the two outer walls. In the SPF DB methods known from the related art for manufacturing hollow blades, nicks, which have a strength-reducing effect, may form inside of the hollow blade. This is disadvantageous.

[0005] Against this background, the object of the present invention is to devise a novel method for manufacturing hollow blades.

[0006] This objective is achieved in that the method mentioned at the outset is further refined by the features set forth in the characterizing portion of claim 1. In accordance with the present invention, at least one nick-minimizing structure is introduced in each case into the first element and the second element which form the two outer walls of the hollow blade to be manufactured, before assembling the same, together with the third element, to form a sandwich-type structure. In the method according to the present invention presented here, an SPF DB method for manufacturing hollow blades is provided, the hollow blades not having any strength-reducing, internal nicks.

[0007] One advantageous further refinement of the present invention provides for the or each nick-minimizing structure to be introduced into an inner side of the first element and of the second element in a way that results in a smaller material thickness for the elements in a middle section than in the lateral sections. Between the middle section and the lateral sections, the elements have a continuous or stepless transitional profile.

[0008] The pressure required for diffusion welding is preferably supplied in such a way that, during the diffusion welding process, the first element and the second element are pressurized in the area of the or of each continuous or stepless transitional profile in such a way that, following the diffusion welding in the area of the or of each transitional profile, a groove space is formed.

[0009] Preferred embodiments of the present invention are derived from the dependent claims and from the following description. The present invention is described in greater detail in the following on the basis of exemplary embodiments, without being limited thereto. Reference is made to the drawing, whose:

[0010] FIG. 1: shows a schematized representation for clarifying a method according to the related art for manufacturing hollow blades;

[0011] FIG. 2: shows another schematized representation for explaining the method according to the related art for manufacturing hollow blades;

**[0012]** FIG. 3: shows another schematized representation for clarifying the method according to the related art for manufacturing hollow blades;

**[0013]** FIG. 4: shows a schematized representation for illustrating the method according to the related art for manufacturing hollow blades;

**[0014]** FIG. 5: shows another schematized representation for clarifying the method according to the related art for manufacturing hollow blades; and

**[0015]** FIG. 6: shows another schematized representation for explaining the method according to the present invention for manufacturing hollow blades.

**[0016]** Prior to describing the method according to the present invention for manufacturing hollow blades in detail in the following with reference to FIG. 4 through 6, the SPF DB method known from the related art for manufacturing hollow blade shall be described first, in order to elucidate the differences between the related art and the invention presented here.

**[0017]** In the SPF (super plastic forming) DB (diffusion bonding) method known from the related art for manufacturing hollow blades, three plate-shaped or sheet-shaped elements 10, 11 and 12 are arranged one over the other in a sandwich-type structure, frame elements or frame strips 13 being positioned between each of two adjacent, plate-shaped elements 10 and 11, as well as 11 and 12. This sandwich-type structure is illustrated in FIG. 1, hollow spaces 14 being formed in those regions in which no frame strips 13 are positioned between two adjacent elements 10 and 11, as well as 11 and 12, respectively.

**[0018]** In accordance with the related art, elements 10, 11, 12 and 13 assembled in this manner one over another in a sandwich-type structure are joined to one another at least in portions thereof by diffusion welding. To this end, the sandwich-type structure of FIG. 1 is placed in a suitable device 15, and a pressure required for diffusion welding is applied to the sandwich-type structure. Elements 10, 11, 12 and 13 are diffusion-welded to one another, at least in portions thereof, under the action of the pressure that is graphically represented by arrows 16. This is illustrated by FIG. 2.

[0019] Thus, in accordance with the related art as shown in FIG. 3, the diffusion-welded stack composed of elements 10 through 13 is superplastically deformed by inflation or blow-up processes. To this end, gas is introduced into the diffusion-welded stack made up of elements 10, 11, 12 and 13, in the direction of arrows 17. During the superplastic deformation process, elements 10 and 12 acquire a shape that corresponds to the desired blade profile of the hollow blade. This blade profile is curved in order to provide an intake side as well as a thrust side for the blades. For the sake of a simpler representation, in FIG. 3, the two elements 10 and 12, which form the outer walls of the hollow blade to be manufactured, extend in parallel to one another following the inflation or superplastic deformation process.

[0020] As can be inferred from FIG. 3, element 11, which extends in between the two elements 10 and 12 functioning as outer walls, takes on the shape of a meander structure in the region between frame strips 13. As can likewise be inferred from FIG. 3, element 11, which extends in between the two elements 10 and 12 functioning as outer walls, is joined in portions thereof to one of the two elements 10 and 12 functioning as outer walls. In those portions in which middle element 11 is not joined to one of the two elements 10 and 12, subsequently to the superplastic deformation, element 11 extends in a zigzag or meander shape between the two elements 10 and 12 forming the two outer walls. To ensure that middle element 11 is joined in parts or portions thereof to the two elements 10 and 12 along the lines of FIG. 3, middle element 11 is coated in sections with an antidiffusion coating, middle element 11 not being joined to elements 10 or 12 in the region of the antidiffusion coating.

[0021] As can be inferred from FIG. 3, under the related art, nicks 19, which seriously degrade the strength of the manufactured hollow blades, form in a transitional region between elements 10 and 12 and frame strips 13.

[0022] The method according to the present invention for manufacturing hollow blades is described in the following with reference to FIG. 4 through 6. In accordance with the present invention, three elements 20, 21 and 22 are again arranged one over another in a sandwich-type structure, joined to one another at least in portions thereof by diffusion welding, and, subsequently to the diffusion welding process, superplastically deformed. A

first element 20 forms a first outer wall of the hollow blade to be manufactured, a second element 22 forms a second outer wall of the hollow blade to be manufactured, and a third element 21, which extends in between the two outer walls of the hollow blade to be manufactured, forms a middle element.

**[0023]** Along the lines of the present invention, nick-minimizing structures are introduced into first element 20, as well as into second element 22, which form the two outer walls of the hollow blade to be manufactured, before assembling the same, together with third element 21, to form a sandwich-type structure. In this context, the nick-minimizing structures are introduced into one inner side 23 and 24 of the two elements 20 and 22, respectively. FIG. 4 shows that, once elements 20, 21 and 22 are assembled to form a sandwich-type structure, inner sides 23 and 24 face middle element 21.

**[0024]** The nick-minimizing structures are constituted of recesses 25 and 26. Recesses 25 and 26 extend as planar regions over respective inner sides 23 and 24 of elements 20 and 22. Recesses 25 and 26 are introduced into inner sides 23 and 24 of elements 20 and 22 in such a way that, in one middle section 27 or 28, elements 20 and 22 have a smaller material thickness or cross-sectional area than in lateral sections 29 or 30. In a transitional region between middle section 27 and 28 and lateral sections 29 and 30, respectively, recesses 25 and 26 exhibit a continuous or stepless transitional profile 31. In cross section, transitional profiles 31 have a circular or elliptical form. Recesses 25 and 26 are machined into inner sides 23 and 24 of elements 20 and 22, respectively, in particular by milling.

**[0025]** In accordance with FIG. 4, elements 20 through 22 designed in this manner are arranged one over another to form a sandwich-type structure, as already mentioned, inner sides 23 and 24 having recesses 25 and 26, respectively, facing middle element 21.

**[0026]** A sandwich-type structure designed in this manner is then diffusion-welded together at least in portions or regions thereof in a diffusion welding process. To this end, here as well, an appropriate pressure is applied to the sandwich-type structure in the direction of arrows 32. The pressure required for diffusion welding is supplied in such a way that, following the diffusion welding process, a groove space 33 is formed in the region of transitional profiles 31. To prevent groove spaces 33 from collapsing during the

diffusion welding process, the pressure required for diffusion welding is supplied by a mechanical press which limits the pressure introduced in the region of transitional profiles 31. FIG. 5 shows the structure that forms following the diffusion welding process, as well as groove spaces 33 which form following the diffusion welding process in the region of transitional profiles 31.

**[0027]** The assembly of elements 20 through 22 diffusion-welded in the above manner is subsequently superplastically deformed, in turn, by inflation or blow-up processes. To this end, by introducing gas into the diffusion-welded structure, pressure acts, in turn, in the direction of arrows 34 on inner sides 23 and 24 of elements 20 and 22. Following the superplastic deformation, a nick-free structure of the hollow blade is produced, particularly in the region of transitional profiles 31 (see FIG. 6).

**[0028]** Accordingly, the method according to the present invention along the lines of FIG. 4 through 6 is distinguished from the known related-art method along the lines of FIG. 1 through 3 in that specially designed elements 20 and 22, which later form the outer walls of the hollow blade to be manufactured, are provided. In this manner, strength-reducing nicks may be avoided, on the one hand, inside of the hollow blade; on the other hand, the need is eliminated for separately formed frame strips. The function of the frame strips required in accordance with the related art is assumed in the method according to the present invention by the lateral sections 29 and 30 of elements 20 and 22, respectively. In this way, the manufacturing method is able to be clearly simplified over the related art.